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Quantum simulations of quantum electrodynamics in Coulomb gauge

In recent years, the quantum computing method has been used to address the sign problem in traditional Monte Carlo lattice gauge theory (LGT) simulations. We propose that the Coulomb gauge (CG) should be used in quantum simulations of LGT. Since the redundant degrees of freedom of gauge fields can be eliminated in CG, the Hamiltonian in CG does not need to be gauge invariance, allowing the gauge field to be discretized naively. Then the discretized gauge fields and fermion fields should be placed on momentum and position lattices, respectively. Under this scheme, the CG condition and Gauss's law can be conveniently preserved by solving for the polarization vectors from algebraic equations. Furthermore, we discuss the mapping of gauge fields to qubits and evaluate the associated qubit and gate cost of this framework. We point out that this formalism is efficient for simulating hadron scattering processes on future fault-tolerant quantum computers. Finally, we calculate the vacuum expectation value of the U(1) plaquette operator and the Wilson loop on a classical device to test the performance of our discretization scheme.

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